Federal Aviation Administration

THE BUSINESS CASE

for the Next Generation Air Transportation System

FY 2013

WHY NEXTGEN MATTERS

The movement to the next generation of aviation is being enabled by a shift to smarter, satellite-based and digital technologies and new procedures that combine to make air travel more convenient, predictable and environmentally friendly.

As demand for our nation's increasingly congested airspace continues to grow, NextGen improvements are enabling the FAA to guide and track aircraft more precisely on more direct routes. NextGen efficiency enhances safety, reduces delays, saves fuel and reduces aircraft exhaust emissions. NextGen is also vital to preserving aviation's significant contributions to our national economy.

NEXTGEN PROVIDES A BETTER TRAVEL EXPERIENCE

- NextGen means less time sitting on the ground and holding in the air. NextGen technology and procedures are shaving crucial minutes off flight times, which translate into money saved and a better overall experience for the traveling public and aviation community.

- NextGen enables the sharing of real-time data about weather, the location of aircraft and vehicles and conditions throughout the National Airspace System. We get the right information to the right people at the right time, helping controllers and operators make better decisions and improve on-time performance.

- NextGen is better for the environment. Flying is becoming quieter, cleaner and more fuel-efficient. Operators are beginning to use alternative fuels and new equipment and procedures, reducing our adverse impact on the environment. More precise flight paths are also helping limit the numbers of people impacted by aircraft noise.

NEXTGEN PRESERVES AVIATION'S ECONOMIC VITALITY

- Our nation's economy depends on aviation. NextGen capabilities in place today are the foundation for continually improving and accommodating future air transportation needs while strengthening the economy locally and nationally with one seamless, global sky.

- Airports are economic engines for the communities they serve, bringing visitors and commerce. NextGen is providing increased access, predictability and reliability, enhancing airport operations across the country.

NEXTGEN ENHANCES SAFETY

- The FAA's top priority is ensuring safe skies and airfields, and NextGen innovation and improvements are delivering just that. NextGen is providing air traffic managers and pilots with the tools to proactively identify and resolve weather and other hazards.

- NextGen enables us to better meet our national security needs and ensure that travelers benefit from the highest levels of safety.

TABLE OF CONTENTS

This report presents the FAA's business case for the Next Generation Air Transportation System (NextGen). NextGen is a wide-ranging transformation of the air transportation system, including air traffic management technologies and procedures; airport infrastructure improvements; and environmental, safety and security-related enhancements. The business case considers only the air traffic management aspects of NextGen, as the costs of these improvements are most directly borne by the FAA and system users. We consider the shortfalls in the current system that new technologies can help to alleviate, and the costs and benefits of doing so.

The business case report considers the improvements described in the NextGen Mid-Term Concept of Operations, most of which are planned for deployment between now and the year 2020. Implementing and maintaining them is expected to cost the FAA and aircraft operators $39 billion through the year 2030. During that period, these improvements are expected to generate $182 billion in total benefits. Applying a 7 percent discount rate, and taking the difference between the present value of benefits and costs, we find that NextGen mid-term improvements have a Net Present Value of $59 billion. This translates to $3.50 in benefits for every $1 invested.

INTRODUCTION

The nation's economy depends on a healthy aviation industry for the transportation of passengers and cargo. The U.S. National Airspace System (NAS) is one of the safest and most efficient in the world today. A number of changes are required to ensure that it remains safe and efficient into the future. During the past several decades, increases in demand have begun to strain some of the system's congested resources, often resulting in longer travel times and increased flight delays. At the same time, high oil prices and concern about the environment have led the aviation industry to look for ways to be more fuel efficient. Fortunately, improved technology is available to help alleviate these problems. GPS-based surveillance and navigation, digital communications and new decision support tools are emerging as ways to help meet the goals of reduced delays, increased efficiency and continued safety. NextGen changes will transform the NAS, making it less reliant on radar surveillance, ground-based navigation systems and voice communications.

This report presents the FAA's business case for the air traffic management elements of NextGen. NextGen is a wide-ranging transformation of the air transportation system, including air traffic management technologies and procedures; airport infrastructure improvements; and environmental, safety and security-related enhancements. This business case addresses only the air traffic management aspects of NextGen, as the costs of these improvements are most directly borne by the FAA and system users. We consider the costs and benefits of addressing the shortfalls of the current system with new technologies.

NextGen has many components. It encompasses multiple programs, procedures and systems at different levels of maturity. This report will focus on those improvements that are described in the NextGen Mid-Term Concept of Operations for the National Airspace System [1] and in the 2013 NextGen Implementation Plan [2]. These improvements are generally planned for initial deployment between now and the year 2020. The Joint Planning and Development Office continues to develop longer-term concepts for transforming the NAS that will build on the mid-term improvements, but these long-term concepts are not considered in this analysis.

This report revises a 2012 estimate of the costs and benefits of NextGen mid-term improvements. Revisions include updates to the FAA's capital budget, updated traffic and fleet forecasts, updated economic factors, improvements to the fast-time model used to estimate most of the operational benefits, changes to planned deployment dates for various operational improvements, and changes to specific program business cases that were incorporated into this analysis.


"The nation's economy depends on a healthy aviation industry for the transportation of passengers and cargo."

NEXTGEN: TOMORROW AT A GLANCE

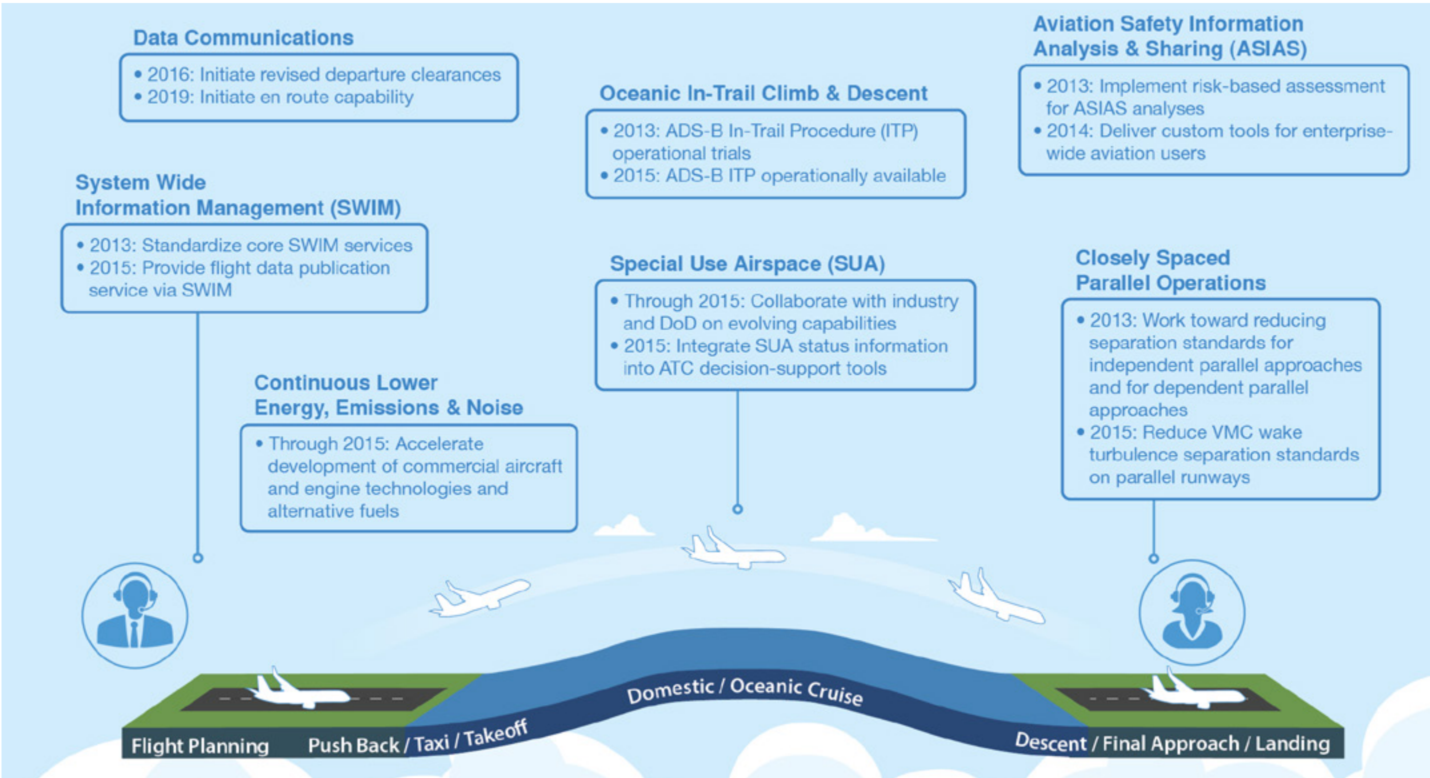


Figure 1. Phases of Flight

NextGen is transforming the National Airspace System (NAS) through a number of Operational Improvements (OI), impacting every phase of flight as shown in Fig. 1. These OIs address shortfalls in various categories, which are grouped into twelve portfolios:

IMPROVED SURFACE OPERATIONS

The Improved Surface Operations portfolio focuses on improved airport surveillance information, automation to support airport configuration management and runway assignments, and enhanced cockpit displays to provide increased situational awareness for controllers and pilots.

TIME-BASED FLOW MANAGEMENT

Improvements in the Time-Based Flow Management portfolio will enhance NAS efficiency by improved metering of flights using time instead of distance. In the near term, these changes will leverage the capabilities of the current Traffic Management Advisor tool, a system that is already deployed to all Contiguous United States Air Route Traffic Control Centers.

PERFORMANCE BASED NAVIGATION

The Performance Based Navigation portfolio leverages state-of-the-art navigation technologies, such as satellite-based Area Navigation and Required Navigation Performance, to improve access and flexibility for point-to-point operations.

ON-DEMAND NAS INFORMATION

The portfolio of On-Demand NAS Information will help ensure that airspace and aeronautical information is consistent across applications and locations and is available to all authorized subscribers and equipped aircraft.

COLLABORATIVE AIR TRAFFIC MANAGEMENT

The Collaborative Air Traffic Management portfolio will better assist NAS operators and FAA traffic managers in managing daily capacity issues such as congestion, special activity airspace, and weather. Enhanced automation will deliver routine information digitally.

IMPROVED MULTIPLE RUNWAY OPERATIONS

The Improved Multiple Runway Operations portfolio is designed to improve runway access through the use of improved technology, updated standards, safety analysis, and modifications to air traffic monitoring tools and operating procedures. It will enable more arrival and departure operations at airports with multiple runways, thereby reducing delays.

IMPROVED APPROACHES AND LOW-VISIBILITY OPERATIONS

The Improved Approaches and Low-Visibility Operations portfolio addresses ways to increase access and flexibility for approach operations through a combination of procedural changes, improved aircraft capabilities and better precision approach guidance.

SEPARATION MANAGEMENT

Improvement in the Separation Management portfolio will provide controllers with tools to manage aircraft in a mixed environment of varying navigation equipment and wake performance capabilities.

ENVIRONMENT AND ENERGY

The Environment and Energy portfolio includes activities leading to the establishment and implementation of the NextGen Environmental Management System, and supports the development of biofuels and more efficient airframe and engine designs.

SYSTEM SAFETY MANAGEMENT

The System Safety Management portfolio develops and implements policies, processes, and analytical tools that the FAA and industry will use to ensure changes introduced with NextGen enhance or maintain safety while delivering benefits.

NEXTGEN INFRASTRUCTURE

The NextGen Infrastructure portfolio contains systems such as Data Communications that serve as enablers for various other capabilities.

CONCEPT MATURITY AND SYSTEM DEVELOPMENT

The Concept Maturity and System Development portfolio includes pre-implementation activities, funded by the NextGen capital budget, for several operational improvements and work that is not yet directly associated with an implementation portfolio. Some activities support multiple OIs.

BENEFIT-COST ANALYSIS OF MID-TERM IMPROVEMENTS

OVERVIEW

The cost and benefit calculations underlying this business case have been developed based on the plans described in the FAA's 2011 Mid-Term Concept of Operations and the 2013 NextGen Implementation Plan. The capabilities that make up the NextGen portfolio will work jointly to deliver the performance improvements described by these documents. Changing the deployment schedule for any enabling technology may alter the timing and magnitude of the benefits derived from the others. Therefore, although each capital program in the FAA is required to demonstrate a positive return on investment on a stand-alone basis before going forward, we believe that a proper cost-benefit analysis of the entire NextGen mid-term must model all improvements jointly in order to capture their interactions.

Our modeling of the benefits and costs of NextGen relies on various inputs. For basic inputs, we rely on traffic data from Fiscal Year 2011, along with traffic and fleet forecasts released in early 2012. Recommended economic values, such as those for passenger value of time, are current as of early 2012. Finally, assumptions about program budgets and deployment schedules are published in FAA's Capital Investment Plan for 2014 – 2018 [3] and the 2013 NextGen Implementation Plan. Changes in any of these input values will cause changes to our results.

Based on these inputs, our analysis shows that NextGen mid-term improvements will generate $182 billion in benefits for the nation through 2030, compared to costs of $39 billion[1]. Fig. 2 illustrates the annual cash flows for these benefits and costs. The following sections present these benefits and costs in more detail. A thorough discussion of the methodology used to generate them can be found in Appendices A and B.

[1] *Unless otherwise noted, all years are fiscal years, and all values are in constant dollars, using Fiscal Year 2012 as the base year. Total cost is the estimated cost of deploying and maintaining NextGen mid-term operational improvements through 2030. This includes FAA Facilities and Equipment, Research and Development, and Operations and Maintenance costs, as well as the cost to system users for avionics upgrades. Total benefit includes the stream of benefits generated by these same operational improvements relative to a baseline scenario.*

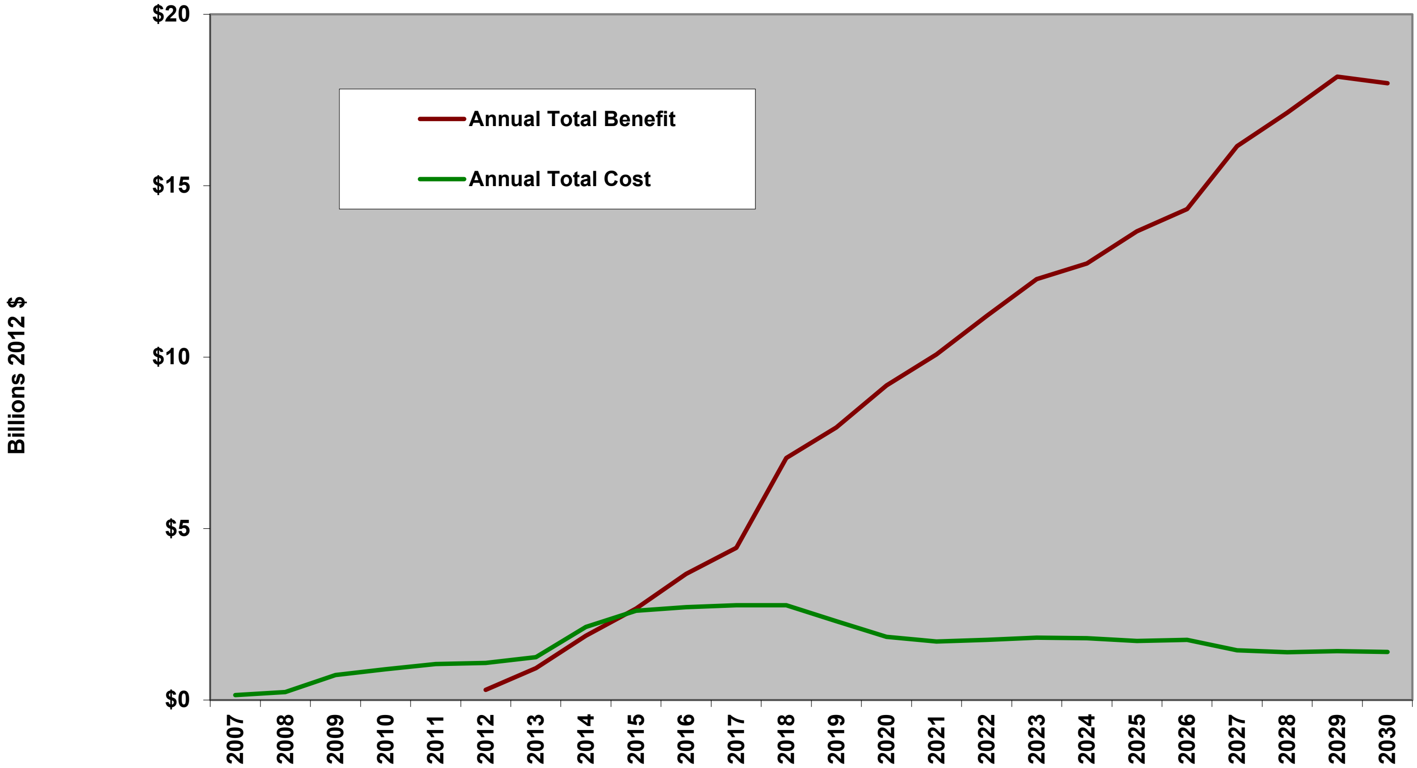


Figure 2. Annual Costs and Benefits of NextGen Mid-Term Capabilities

ESTIMATED BENEFITS OF NEXTGEN IMPROVEMENTS

The business case focuses on the direct benefits to aircraft operators, passengers and taxpayers from the rollout of NextGen improvements. These benefits include aircraft operating cost savings, passengers' value of time, reduced operating costs for the air traffic control system and improved safety and environmental benefits from reduced aircraft emissions[2]. The business case does not consider the second-order economic benefits that may accompany major technology initiatives, such as job creation and economic growth. We also do not attempt to model planned NextGen improvements in such areas as bio-fuels and improved engine technologies. The FAA does not directly provide these benefits, but the FAA supports these efforts with research funding.

The primary means of estimating these benefits is through the use of fast-time simulation modeling, specifically the FAA's System Wide Analysis Capability (SWAC). Evaluating NextGen benefits requires a comparison of two complete scenarios — a baseline scenario with no new NextGen improvements and a second scenario with the planned improvements. The benefits of the system improvements are then the difference between the two scenarios in terms of the number of flights, number of cancellations, average time per flight and fuel consumed.

Because many NextGen benefits are based on the interaction of new communications, surveillance and navigation technologies rather than individual elements taken in isolation, estimating the NextGen benefits requires a comprehensive assessment of all improvements taken together. While we are continuously improving our model, we are not yet able to model all of the NextGen planned capabilities. We supplement our modeled benefits using program-specific investment analyses whenever necessary. We take care to avoid double-counting.

Most NextGen benefits are related to the additional airspace capacity and efficiency that the new system is anticipated to provide. Time savings are valued in terms of dollars per minute, using estimates of aircraft direct operating cost (ADOC) and passengers' value of time (PVT). A consumer surplus approach assigns value to those additional flights that will be enabled by greater system capacity. We also value the estimated benefit of reduced flight cancellations and reduced

[2] *While NextGen is expected to reduce emissions of particulate matter and oxides of nitrogen and sulfur, only reductions in carbon dioxide emissions have been included in this business case thus far. Likewise, changes in noise exposure have not been considered.*

carbon dioxide emissions. Finally, estimates of FAA cost savings and improvements in system safety are adapted from other sources.

The resulting cumulative benefit estimates from 2012 through 2030 are

- Avoided delay — $47 billion in ADOC and $107 billion in PVT — by far the largest component[3]
- Reduced flight time — $5.9 billion
- Fewer flight cancellations — $3.4 billion
- Reduced CO_2 — $379 million
- Other miscellaneous benefits not derived from FAA's fast-time model, including safety improvements, FAA cost savings, and others — $17.7 billion.

Total benefits per year are shown in Fig. 3.

ESTIMATED COSTS OF NEXTGEN IMPROVEMENTS

Transforming the nation's air traffic management infrastructure is a major undertaking. Ensuring that NextGen moves forward as scheduled — and therefore delivers benefits to NAS stakeholders as promised — will require timely investments on the part of both the government and aircraft operators.

Government investment includes the hardware and software required to implement NextGen, along with the system development and program management tasks associated with deploying this infrastructure. The FAA's total investment in NextGen is projected to be $20 billion through 2030 to achieve mid-term improvements in constant 2012 dollars.

- Capital expenditures from the agency's Facilities and Equipment (F&E) budget are expected to be $11 billion through 2030.
- Other funding is included in the agency's Research and Development (R&D) budget line. Through 2030, R&D and related expenditures on NextGen are projected to be $1 billion.
- We also estimate the amount that the FAA will need to spend on Operations and Maintenance costs. These costs are projected to total about $8 billion through 2030.

Investment by aircraft operators is also expected to be

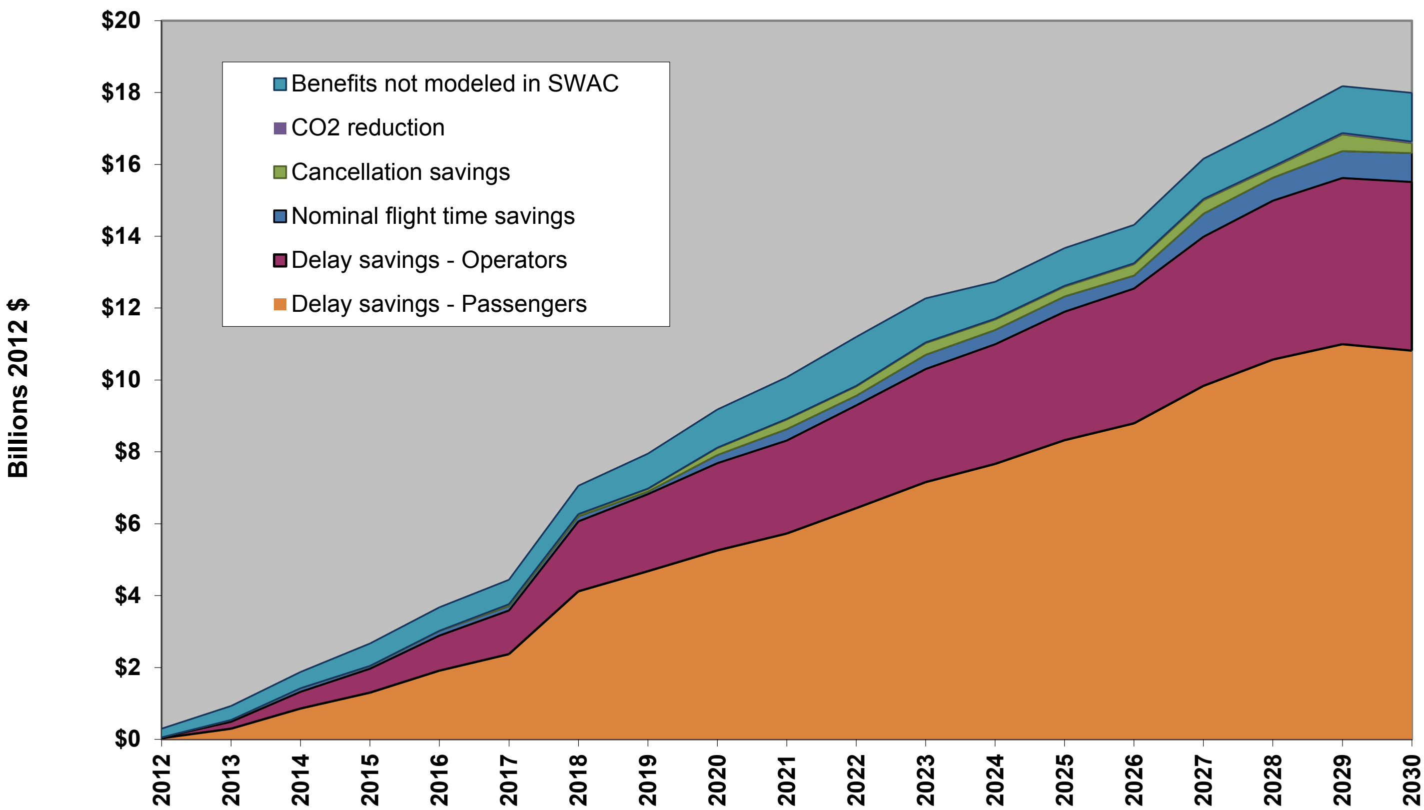


Figure 3. Annual Benefits of NextGen Mid-Term Capabilities

[3] *In this cost-benefit analysis, delay refers to time in excess of that anticipated, no matter how small. While delays in excess of 15 minutes are all that are reported for operational purposes, all delays are included for FAA cost-benefit analyses.*

significant. This investment includes the purchase and installation of the avionics necessary to take advantage of NextGen capabilities. The technologies we consider are Automatic Dependent Surveillance–Broadcast (ADS-B) Out, ADS-B In, Data Communications and Required Navigation Performance. Together, these costs are expected to total $19 billion through 2030. While most of these expenses will be borne directly by aircraft owners and operators rather than by the FAA, they are an important component of the overall investment for NextGen. These annual costs are shown in Fig. 4.

More details on the cost estimates and the methodology used to derive this information are in Appendix B.

INVESTMENT ANALYSIS

Deploying NextGen is a major capital project for the FAA and for the air transportation industry. It will take several years to install NextGen-ready avionics across the fleet, deploy the ground infrastructure and develop the new procedures that support NextGen improvements. Over time, the annual benefits of NextGen will increase as new capabilities are brought into service. The chart in Fig. 5 shows the cumulative costs and benefits of deploying NextGen mid-term improvements.

Standard investment analysis requires that future costs and benefits be discounted to reflect the fact that a dollar paid or received in the future is worth less than a dollar paid or received today. To calculate these discounted (or present) values, we use the standard rate of 7 percent per year recommended by the Office of Management and Budget [4] to discount all benefits and costs. This approach yields the values shown in Fig. 6.

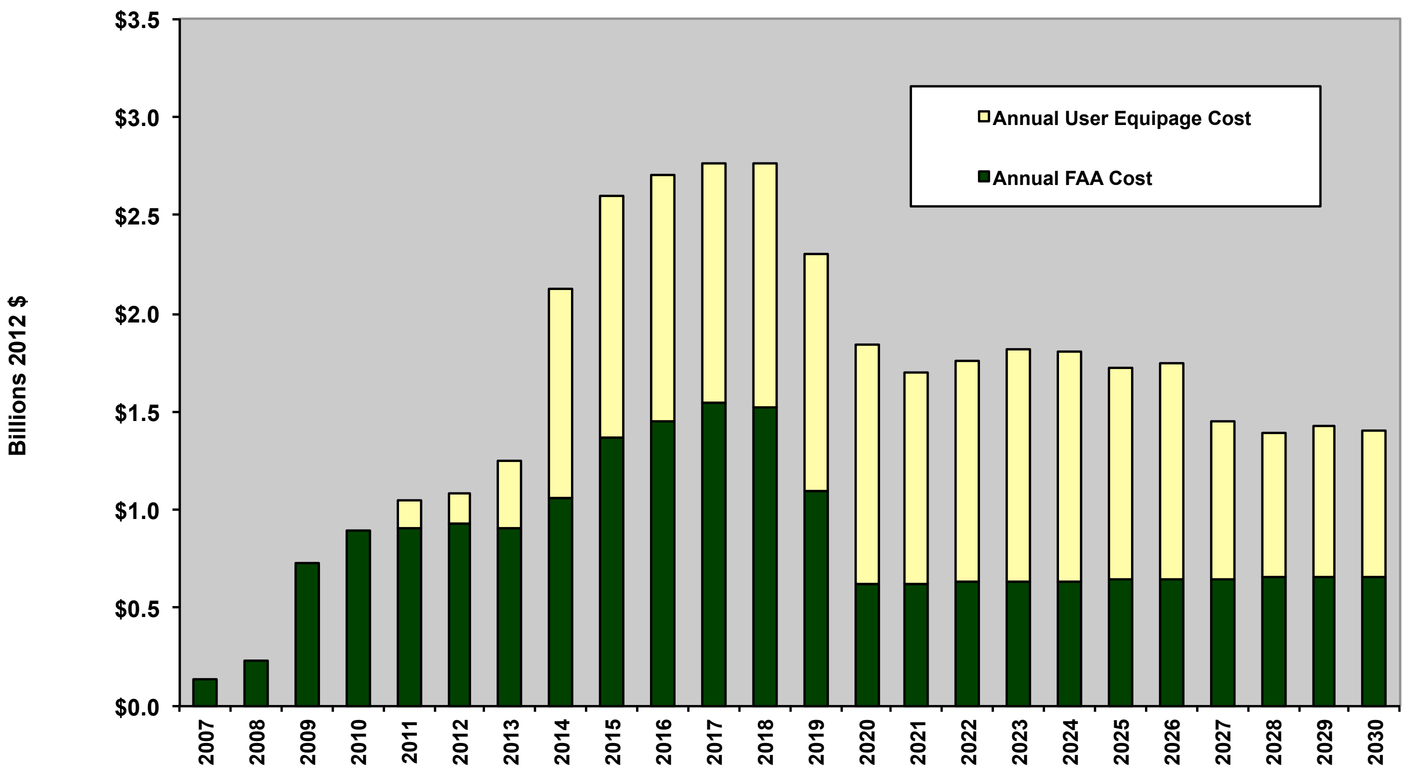


Figure 4. Annual Cost of NextGen Mid-Term Capabilities

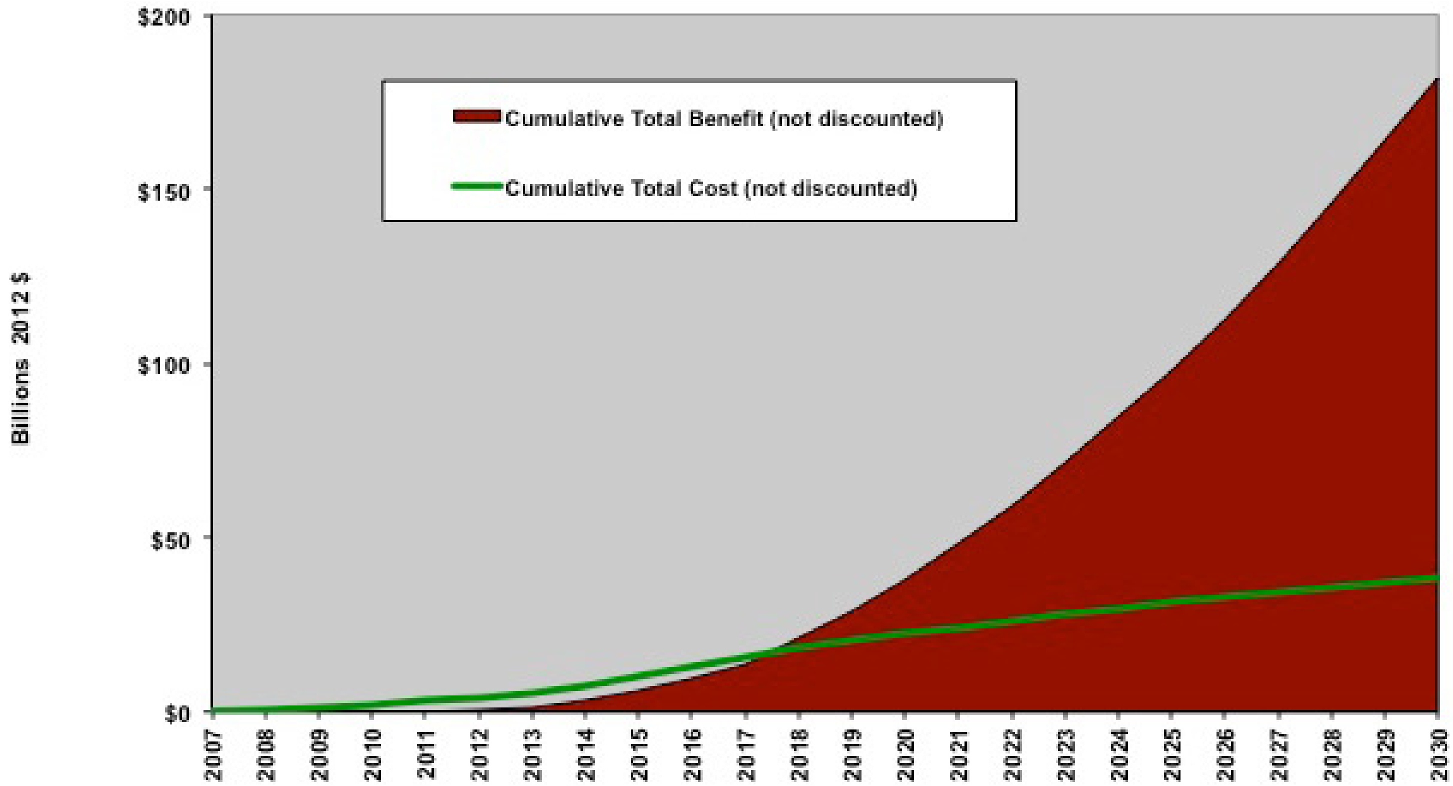


Figure 5. Cumulative Costs and Benefits of NextGen Mid-Term Improvements

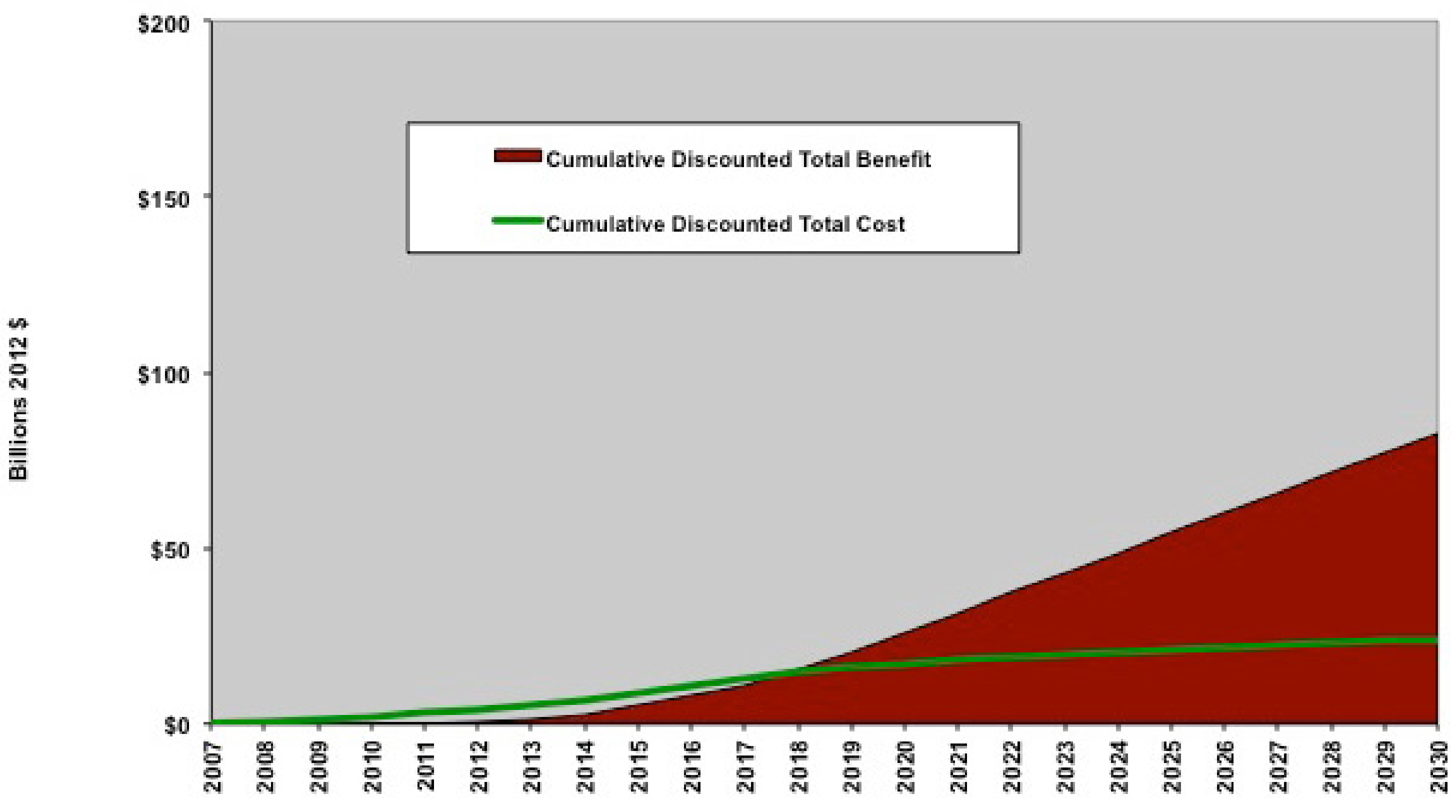


Figure 6. Discounted Cumulative Costs & Benefits of NextGen Mid-Term Improvements

Although significant investments will be required to prepare for NextGen operations, the cumulative discounted benefits will begin to exceed the cumulative discounted costs by 2018. By 2030, cumulative discounted benefits will exceed discounted costs by $59 billion, for a benefit-to-cost ratio of 3.5-to-1. A common way to illustrate the annual impact of capital investment programs in present value terms is to show the cumulative discounted benefits less the cumulative discounted costs for each year (the Net Present Value, or NPV), as shown in Fig. 7. This chart clearly illustrates program breakeven in 2018 and the NPV of $59 billion by 2030. To demonstrate further the strength of the business case, the chart also shows the analysis without considering passenger time savings. Excluding these savings, NextGen still results in an NPV of $8 billion and a breakeven in 2025, with a benefit-to-cost ratio of 1.3 to 1.

CONCLUDING THOUGHTS

The goal of NextGen is to take U.S. air transport firmly into the 21st Century. There are many pieces to the program — research and development, ground infrastructure, computer software, airspace design, flight procedures and new aircraft avionics. In producing the business case report, we have endeavored to link NextGen's benefits with those investments and activities that are necessary to generate them. We have attempted to capture all relevant costs and benefits.

Our analysis shows that by 2030, NextGen's mid-term improvements will have yielded $3.50 in benefits for every $1 invested. It is our goal to continuously improve the quality of our forecasts of future benefits and costs. We anticipate that our estimates will change over time as our methodologies improve and as our expectations of future traffic and capacity evolve. We do not expect the fundamental conclusion of this analysis to change — NextGen is a good investment for our country.

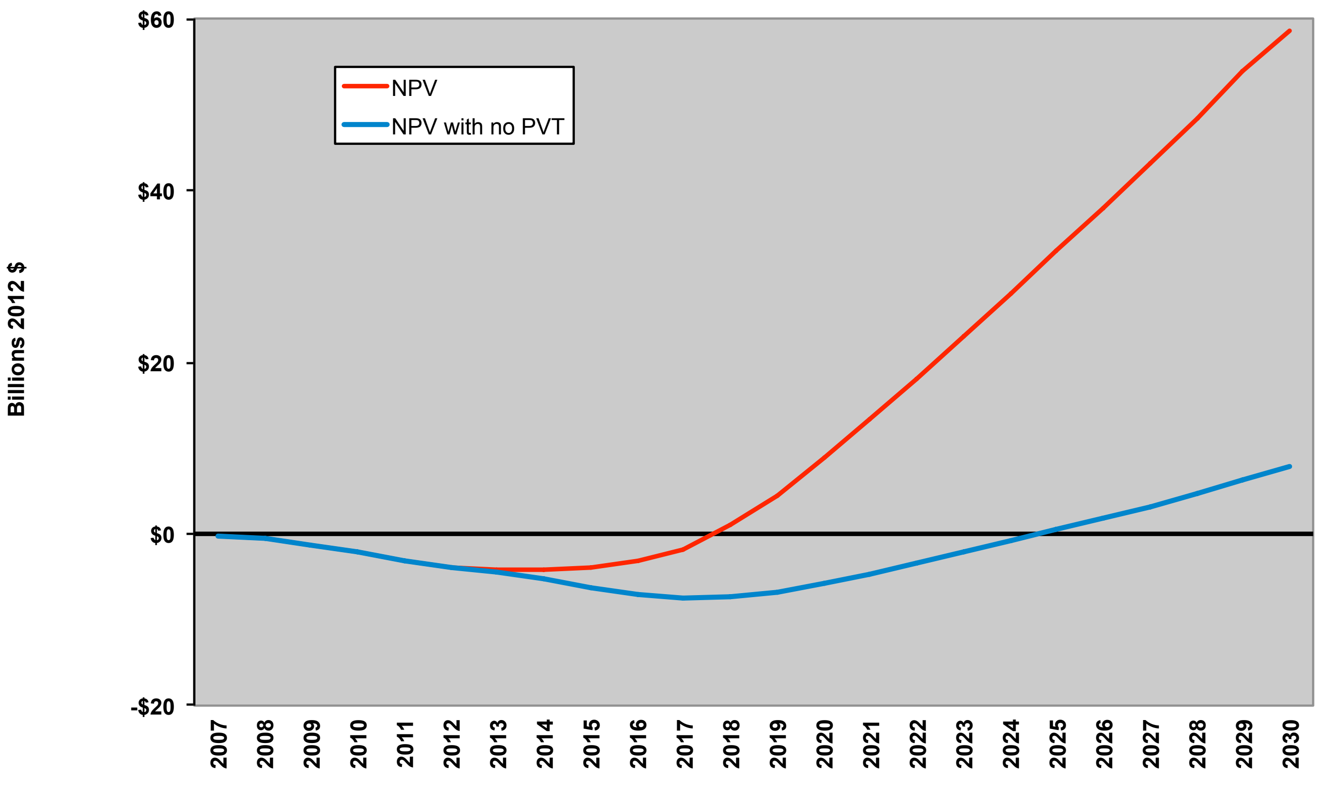


Figure 7. NextGen Mid-Term Investments Net Present Value (NPV) by Year

APPENDIX A: BENEFITS METHODOLOGY

Appendix A explains how the FAA's system-wide model is used to evaluate benefits, which operational improvements are currently being modeled, and which operational improvements are assessed using supplemental studies.

The interdependent nature of NextGen capabilities means that benefits must be calculated for the program as a whole rather than by a sum of its components. NextGen's components are steps in a wide-ranging overhaul of the air traffic management system, not incremental improvements to the existing system. To the extent possible, the FAA's business case for NextGen recognizes this situation by taking an integrated approach to modeling system-wide benefits. A system-wide mathematical model of the National Airspace System (NAS) is used to estimate the benefits of the entire program, to account for the interdependencies and non-linearities within the system. While the FAA's modeling capability has improved tremendously in recent years, significant modeling limitations remain. Specifically, many operational improvements cannot be adequately represented in the model. For this reason the benefits estimates produced by the model are augmented with detailed, discrete studies performed by FAA program offices and others where appropriate. In future editions of the NextGen Business Case, we anticipate more benefits will be captured using the model with less reliance on additional studies. Doing so will yield a more accurate and comprehensive representation of total program benefits.

USING FAA'S SYSTEM-WIDE ANALYSIS CAPABILITY TO ESTIMATE BENEFITS

For the purposes of this analysis, NextGen benefits are considered to be the difference between a "Base Case" which includes no further enhancements beyond planned new runways, and a "NextGen Case" that includes estimated capacity and efficiency improvements from the mid-term operational improvements that are modeled. While new runway infrastructure projects are at times considered part of the overall NextGen program, much of the cost of such projects is borne by local communities. Anticipated future runway infrastructure is not treated as a "NextGen" improvement in this report, but is instead included in the Base Case.

The FAA's System Wide Analysis Capability (SWAC) is a fast-time simulation model used to estimate the potential benefits of NextGen improvements in the NAS. SWAC can calculate delay, canceled flights and fuel burn savings along with the potential for an increase in accommodated flights achieved by the various NextGen mid-term improvements working together.

At its core, SWAC is a discrete-event queuing model. NAS resources that may be capacity constrained — such as sectors, arrival or departure fixes, or airports — are represented as "servers" in the queuing model. SWAC

contains server representations for all en route sectors in contiguous United States airspace, 310 domestic airports, terminal airspace at the 35 busiest airports and in-trail constraints for aircraft entering oceanic airspace[4]. In order to represent the demand on those servers, each flight is modeled at a detailed level.

To generate the traffic demand on NAS resources, SWAC begins with actual flight data from the FAA's Traffic Flow Management System. Drawing from a representative set of recent historical days, all flights that filed an Instrument Flight Rules (IFR) flight plan and flew in the NAS are gathered as the baseline set of flights[5]. These flights are then augmented with Visual Flight Rules (VFR) arrivals and departures from the FAA's Operations Network data. Current traffic levels are also projected into future years using the FAA's Terminal Area Forecast [5]. If this future traffic projection leads to demand at any airport that is infeasible, given the airport's capacity, then flights are removed; they are assumed not to be scheduled and flown[6].

When looking at future scenarios, the FAA's domestic airline fleet forecast is used to represent changes in the airframes being modeled. This is mainly done to more accurately represent future fuel usage and carbon dioxide emissions. These aircraft are also modeled as having a certain avionics equipage, which changes over time. This equipage may be NextGen related, and can be used to estimate the benefits of certain types of avionics. Other NextGen enhancements allow for the modification of the filed route of flight, e.g. Q-Routes, or allow for continuous ascent or descent profiles. Each IFR flight has its trajectory computed and interpolated in 4-D using Eurocontrol's Base of Aircraft Data (BADA) [6], using historical data on winds aloft for the particular day being modeled[7]. These interpolated trajectories, combined with assumptions about aircraft type, allow for detailed estimates of time in flight and fuel used.

Along with demand, capacity is a key component to the model. Sector capacity estimates are based on traffic flow management monitor alert parameters, and are modified

[4] *SWAC represents all IFR flights that enter, exit, or transition through U.S.-controlled airspace. However, some U.S. airports (310 for this analysis) are capacity constrained in the model. All other airports are assumed to have infinite capacity.*

[5] *For this analysis a set of 16 days from FY2011 were used to represent the entire year. These days were selected using an optimization technique to ensure that derived annual totals for airports and Air Route Traffic Control Centers were as close to observed values as possible.*

[6] *When NextGen improvements are projected to increase capacity at constrained airports, some of these removed flights may be added back in, which becomes a quantifiable benefit.*

[7] *We use the National Centers for Environmental Prediction/National Center for Atmospheric Research Global Reanalysis Model wind and pressure estimates for the SWAC trajectory model.*

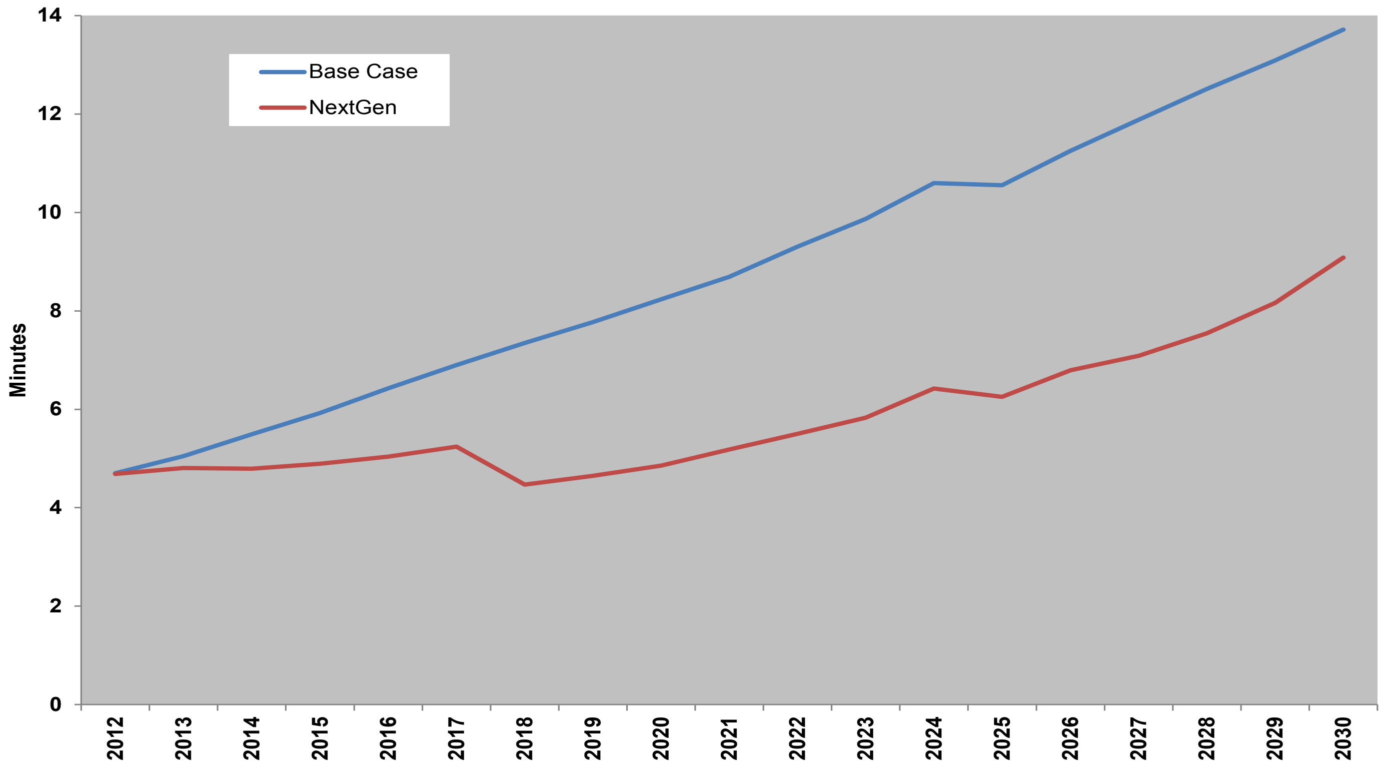


Figure 8. Average Delay Minutes per Flight from SWAC

during simulation execution using National Convective Weather Diagnostic (NCWD) data. Airport capacities are estimated using MITRE's runwaySimulator model, for at least three surface weather conditions for each airport; visual, instrument, and marginal visual. Meteorological Aerodrome Report (METAR) data is then used by SWAC to determine local airport conditions and which airport arrival and departure capacities to use at any given time during the simulation. Historical weather data is obtained from the National Weather Service's National Climatic Data Center.

Once initial demand and capacity have been estimated, SWAC performs one last calculation before starting the queuing model. A module is run to determine if any ground delay programs need to be implemented to account for bad weather, for example. This computation allows for more accurate estimates of flight time, fuel usage and sector congestion, by shifting delay to the surface that might otherwise have been taken in the air.

Finally, the queuing model is run, and delays are computed, along with the corresponding fuel burn. The resulting differences in flight times, scheduled flights and cancelled flights between the NextGen Case and the Base Case represent the impact of NextGen. The valuation of these differences in dollar terms is covered in the next section.

The largest modeled benefits come from reduced delays. Although our modeling shows a marked improvement in delay minutes compared to a future without NextGen, delay in either case is forecast to increase. It will simply increase less with NextGen, as shown in Fig. 8. This is a consequence of the large increase in air traffic that the FAA forecasts over the next 20 years.

VALUING MODELED IMPROVEMENTS IN NAS PERFORMANCE

Differences between modeled performance with and without NextGen improvements are measured in the following categories:

Improvements in system capacity utilization

- Reductions in flight, taxi, and gate times and corresponding fuel use resulting from less delay
- Reductions in cancelled flights
- Additional scheduled flights that are enabled by increased airport throughput

Improvements in system efficiency

- Reductions in flight times and fuel use due to more direct routings
- Reductions in flight times and fuel use due to more efficient climb and descent profiles.

VALUING REDUCTIONS IN FLIGHT TIMES AND FUEL USE

To evaluate the monetary value of changes in flight times, we apply the FAA's standard method of using aircraft direct operating cost (ADOC) and passenger value of time (PVT). This method is applied to any change in flight time — whether due to reductions in delay or improvements in flight efficiency.

AIRCRAFT DIRECT OPERATING COST (ADOC)

Aircraft direct operating cost is used to measure the impact of changes in flight times on aircraft operators. We start by using the FAA's official ADOC values [7], which include the costs of fuel and oil, crew and maintenance for large passenger carriers, cargo, military and general aviation. Because the SWAC model can estimate fuel use, which enables us to calculate the fuel cost directly, we exclude the fuel cost component from the ADOC values. We then derive unique ADOC values (excluding fuel) specifically for each of the BADA aircraft types and user classes modeled in SWAC[8]. Thus the value of time and fuel savings for aircraft operators is the sum of crew and maintenance costs and fuel cost, given by the formula:

$$Value\ of\ Time\ Savings\ (ADOC) = \sum_f \left[minutes\ saved_f \times \left(\frac{crew\ and\ maintenance\ cost}{minute} \right)_{a,u} \right] + \sum_f \left[(excess\ fuel\ use)_f \times (jet\ fuel\ price) \right]$$

Where

f = flight segment

a = BADA aircraft type

u = user class (commercial passenger service, cargo, etc.)

Value of Time Savings (ADOC)

PASSENGER VALUE OF TIME (PVT)

Based on the latest guidance dated September 28, 2011, from the Department of Transportation, the PVT base value has increased from $28.60 per hour to $43.50 per hour, with 1.6 percent real growth per year thereafter [8]. Combining these PVT estimates, along with estimates of the number of seats and the load factor, the value of time savings for passengers is calculated as:

$$Value\ of\ Time\ Savings\ (PVT) = \sum_f \left[minutes\ saved_f * \frac{PVT}{minute} * seats_{a,u} * load\ factor_{a,u} \right]$$

Where

f=flight segment

a=BADA aircraft type

u=user class (commercial passenger service, cargo, etc.)

Value of Time Savings (PVT)

[8] For new aircraft types that are not yet in service, we first chose a surrogate aircraft and then scaled the fuel cost by the estimated fuel consumption of the new aircraft type. We estimated crew and maintenance costs using the anticipated number of seats on the aircraft.

VALUE OF CARBON DIOXIDE REDUCTIONS

Reduced flight times and delays will also reduce fuel use. We estimate that NextGen will save 8.3 billion gallons of fuel through 2030. While the direct cost of fuel to aircraft operators is already included in the ADOC calculations above, the environmental benefits to society as a whole are not. We therefore need to value the positive externality of reduced carbon dioxide emissions. First, we convert fuel savings into carbon dioxide, using a standard conversion formula. Then we value the change in carbon dioxide using a concept known as the social cost of carbon, or SCC. Annual values for the SCC have been estimated by the U.S. Interagency Working Group on the Social Cost of Carbon [9]. The resulting benefit valuation is given by the following formula:

$$Value\ of\ CO_2\ Reduction = \ (gallons\ of\ fuel\ saved)_y * \left(\frac{21.095\ lbs\ CO_2}{gallon\ of\ fuel}\right) * \left(\frac{1\ metric\ ton}{2204.62\ lbs\ CO_2}\right) * (SCC_y)$$

Where

$SCC = social\ cost\ of\ carbon\ per\ metric\ ton\ of\ CO_2$

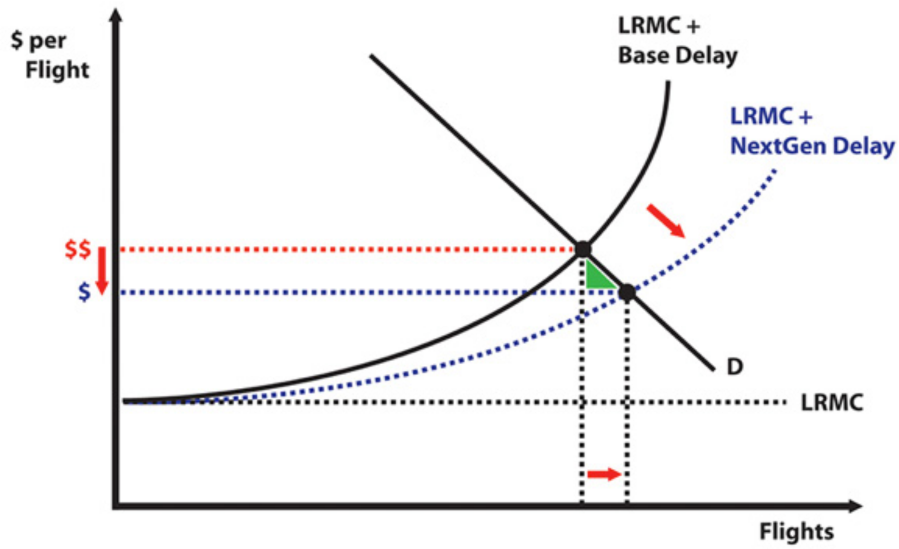
$y = year$

Value of CO_2 Reduction

VALUING ADDITIONAL FLIGHTS ENABLED

Capacity increases will allow more flights to be scheduled and flown at capacity-constrained airports. Thus, counting the benefit of reduced delay for existing flights is not sufficient. However, we must be careful when valuing these additional flights. It would be incorrect to count the additional revenue generated, which would be the average ticket price multiplied by the number of additional passengers served. In general, air carrier revenue is a transfer from passengers to flight operators in exchange for a service provided. If the service was not provided, the passengers would have spent their money elsewhere. There is a benefit from additional flights that can be described by the concept of consumer surplus. While a thorough treatment of the concept of consumer surplus is beyond the scope of this report, this surplus reflects the consumers' "willingness to pay" for a product or service. In general, there are many consumers who are willing to pay more than the market price for the service, in this case air transportation. The sum total of this willingness to pay across all consumers in the market is the consumer surplus. If the cost to consumers goes down, consumer surplus increases because more people pay less than they otherwise would for the same service.

The reason for additional flights is a reduction in the cost of providing them. In this case, the decrease in cost is brought about by reduced delays. Thus, new flights are valued using the marginal reduction in delay cost, multiplied by the marginal increase in the number of flights enabled by this delay cost reduction. Graphically, this is the area under the demand curve between the old and new number of flights, as shown in Fig. 9.



LRMC is "Long Run Marginal Cost", defined as the cost of providing a flight in the absence of delay

Figure 9. NextGen's Impact on Supply and Demand Relationships for Air Transportation Services

Assuming a linear demand curve with a slope of -1, the value of additional flights is then given by the equation:

$$Value\ of\ Additional\ Flights = \frac{1}{2}(\Delta\ delay\ cost\ ) * (\Delta\ flights)$$

Value of Additional Flights

VALUING REDUCTIONS IN THE NUMBER OF CANCELLED FLIGHTS

Flight cancellations are costly to airlines and passengers. However, at some point it is preferable to cancel a flight rather than incur even higher costs if delays become excessive.

There is no generally accepted cost of cancellations for use in Government cost-benefit studies, as there is with ADOC or PVT. However, several studies have investigated the issue, and we rely on two of them [10], [11]. Based on these studies, aircraft operators are assigned a fixed cost of $4,977 per cancellation, while the cost to passengers is based on applying PVT values to an estimated average of 457 minutes of passenger delay per cancelled flight[9]. Mathematically, these are calculated as follows:

$$Value\ of\ Reduced\ Cancellations\ (airlines) = (\Delta\ cancelled\ flights) * \left(\frac{\$4{,}977}{Flight}\right)$$

$$Value\ of\ Reduced\ Cancellations\ (passengers)$$

$$= (\Delta\ cancelled\ flights) * \left(\frac{PVT}{min}\right) * \left(\frac{457\ min}{passenger}\right) * \left(\frac{passengers}{flight}\right)$$

Value of Reduced Cancellations

[9] *This estimated value of passenger delay includes the average time lost due to having to re-book on a different flight.*

MID-TERM OPERATIONAL IMPROVEMENTS MODELED

In its current iteration, SWAC models a subset of NextGen-enabled improvements to the operating environment. Nearly 85 percent of the cumulative benefits by value are modeled directly in SWAC. The remaining benefits are based on FAA Program Office studies. Tables 1 and 2 present those operational improvements currently modeled[10]. As the SWAC model continues to develop, it will identify and capture a greater share of total benefits.

Table 1. Portfolio Operational Improvements Modeled in SWAC

Portfolio	Operational Improvements
Collaborative Air Traffic Management (CATM)	User Tactical Trajectory Feedback (104102-21)
	User Trajectory Planning in Pre-Oceanic Phase (104102-23)
	Flexible Airspace Management (108206)
Time Based Flow Management (TBFM)	Implement TMA's ACM Capability at Additional Locations (104115-11)
	Implement TMA at Additional Airports (104115-12)
	Extended Metering (104120-11)
	Arrival Interval Management Using Ground Automation (104120-13)
	Metering during Reroute Operations (104120-21)
	Use RNAV Data to Calculate Trajectories used to Conduct TBM Operations (104123-11)
	Metering to Fixes Within Terminals (104128-23)
Improved Multiple Runways Operations	Wake Turbulence Mitigation for Departures (102140)
	Additional 7110.308 Airports (102141-11)
	Wake Turbulence Mitigation for Arrivals – Procedures for Heavy/Boeing 757 Aircraft (102141-11a)
	Implement Satellite Navigation or Instrument Landing System for Parallel Runway Operations (102141-12)
	Amend Independent Runway Separation Standards in Order 7110.65 (including Blunder Model Analysis) (102141-13)
	Enable Additional Approach Options for New Independent Runway Separation Standards (102141-13a)
	Amend Dependent Runway Separation Standards in Order 7110.65 (102141-14)
	Wake Turbulence Mitigation for Arrivals: System for Closely Spaced Parallel Runways not Eligible for 7110.308 (WTMS-S) (102144-21)
	Use Converging Runway Display Aid (104109-12)
Improved Approaches and Low-Visibility Operations	Initial Tailored Arrivals (104124-11)
	OPDs using RNAV Standard Terminal Arrival (104124-12)
	GBAS Category I Non-Federal System Approval (107107-11)
	GBAS Cat II/III Standards (107107-21)
	Expanded Low Visibility Operations Using Lower Runway Visual Range Minima (107119)
Performance Based Navigation	Expanded Use of 3nm Separation in Transition Airspace (104122-21)
	NextGen En Route Distance Measuring Equipment (108209-11)
	Optimization of Airspace and Procedures in the Metroplex (108209-12)
	Large-Scale Redesign of Airspace Leveraging PBN (108209-13)
	Transition to PBN Routing for Cruise Operations (108209-14)
	Relative Position Indicator (108209-15)
	PBN Route Eligibility Check (108209-18)
	RNAV (GPS) Approaches (108209-19)
	Advanced and Efficient RNP Procedures (108209-20)
Separation Management	Delegated Responsibility for In-Trail Separation (102118)
	ADS-B Separation (102123)
	Reduced Oceanic Separation and Enhanced Procedures (102136)
	ADS-Contract Oceanic Climb/Descent Procedure (102108-11)
	Enhanced Oceanic CDP via ADS-C Automation (102108-12)
	En Route Conformance Monitor for PBN Routes (102114-21)
	Initial En Route Data Communication Services (102114-23)
	En Route Radar Controller Conflict Probe (102114-30)
	Wake Re-Categorization Phase I – Aircraft Re-Categorization (102154-11)

[10] *The numbers in parentheses are the identifiers for the operational improvements in the FAA's NAS Enterprise Architecture [12].*

Table 2. Benefits Not Included in Table 1 (Estimated from Other Sources)

CATM Technologies
ADS-B Safety, Efficiency and Cost Avoided Benefits
Data Communications - FAA Efficiency Benefits & Tower Departure Clearance Services
System Wide Information Management
TBFM
Aeronautical Information Management
Common Support Services–Weather*

* Formerly NextGen Network Enabled Weather

APPENDIX B: COST METHODOLOGY

Implementing the NextGen transformation will require significant investments from the FAA to fund the deployment of NextGen technologies, as well as from aircraft operators, who are responsible for ensuring that their aircraft are properly equipped to maximize performance in the future National Airspace System. This chapter discusses the projected costs of mid-term NextGen improvements for the FAA and aircraft operators, along with the methodology used to derive them.

COST TO THE GOVERNMENT

FACILITIES AND EQUIPMENT (F&E)

Estimates of the FAA's costs to develop and implement NextGen technologies are derived from internal agency budget estimates. The agency's F&E budget request for the next five fiscal years is published in the Capital Investment Plan (CIP). The budget numbers contained in the CIP come from bottom-up cost estimates that are developed by the individual capital programs within the FAA. For many NextGen programs the published five-year time horizon does not cover their entire development period. In these cases, the published CIP must be supplemented with cost estimates beyond the published five-year horizon, which are also provided by the individual FAA program offices. The NextGen F&E budget consists of transformational programs, implementation programs, and pre-implementation activities. The programs and activities in each of these categories are listed in Table 3.

Table 3. Categories of NextGen F&E Expenditures

NextGen Transformational Programs	NextGen Implementation Programs	NextGen Pre-Implementation Activities
Automatic Dependent Surveillance–Broadcast	Time Based Flow Management	NextGen Demonstrations and Infrastructure Development
System Wide Information Management	Colorado Wide Area Multilateration	NextGen System Development
Collaborative Air Traffic Management Technologies	Aeronautical Information Management	NextGen Trajectory Based Operations
Data Communications	En Route Automation Modernization	NextGen Reduce Weather Impact
National Airspace System Voice System	NextGen Future Facilities	NextGen Arrivals/Departures at High Density Airports
Common Support Services– Weather *	Performance Based Navigation	NextGen Collaborative Air Traffic Management
	Tower Flight Data Manager	NextGen Flexible Terminals and Airports
	Security Integrated Tool Set Work Package 1	NextGen Safety, Security, and Environment
	Aviation Safety Information Analysis & Sharing	NextGen Systems Networked Facilities
	NextGen Weather Processor	Joint Planning & Development Office (JPDO)

* Formerly NextGen Network Enabled Weather

The official budget request for each of these F&E activities can be found in the latest published CIP. The exact values used for the analysis contained in this document were based on CIP requests for 2014 – 2018, and are consistent with the assumptions underlying the benefit estimates presented in other sections. These F&E costs are shown in Fig. 10.

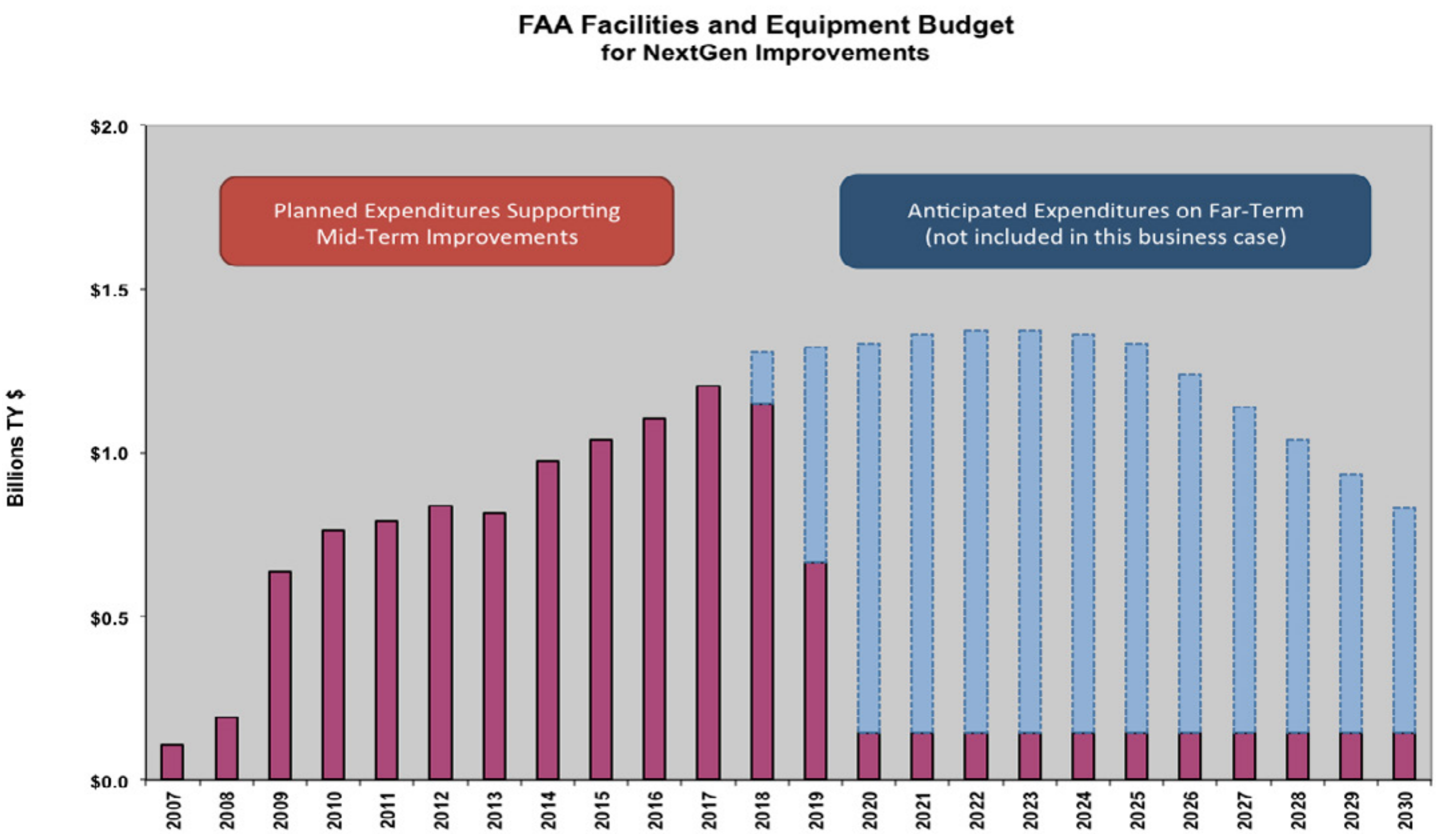


Figure 10. Estimated Annual F&E Cost to the FAA for NextGen Improvements

R&D AND RELATED COSTS

Like the CIP, the agency's Research and Development (R&D) budget needs are laid out in the National Aviation Research Plan covering the next five fiscal years [13]. As with the CIP, we must also go beyond this horizon in order to accurately assess the cost of NextGen R&D. Unlike FAA capital programs, the exact allocation of these R&D funds is nearly impossible to predict beyond a few years out. Along with the pre-implementation activities, we make the assumption that R&D funding used on mid-term operational improvements will gradually diminish as the time horizon for deployment of all mid-term technologies nears completion around 2020.

OPERATIONS AND MAINTENANCE

Historical examples of baselined business cases for FAA capital programs suggest that annual Operations and Maintenance (O&M) costs average about 5 percent of the total capital costs of system deployment. We have used this relationship to estimate the O&M costs of all the NextGen mid-term programs. Beginning in 2015, we have assumed that annual O&M costs will equal 5 percent of the cumulative F&E budget from 2007 through the prior year. For example, in 2015 O&M costs are estimated to equal 5 percent of the total F&E budget from 2007 through 2014. O&M costs in 2016 are estimated to equal 5 percent of the total F&E budget from 2007 through 2015, etc. Fig. 11 shows the total estimated FAA cost for NextGen programs, broken out by F&E, R&D and Ops, and O&M.

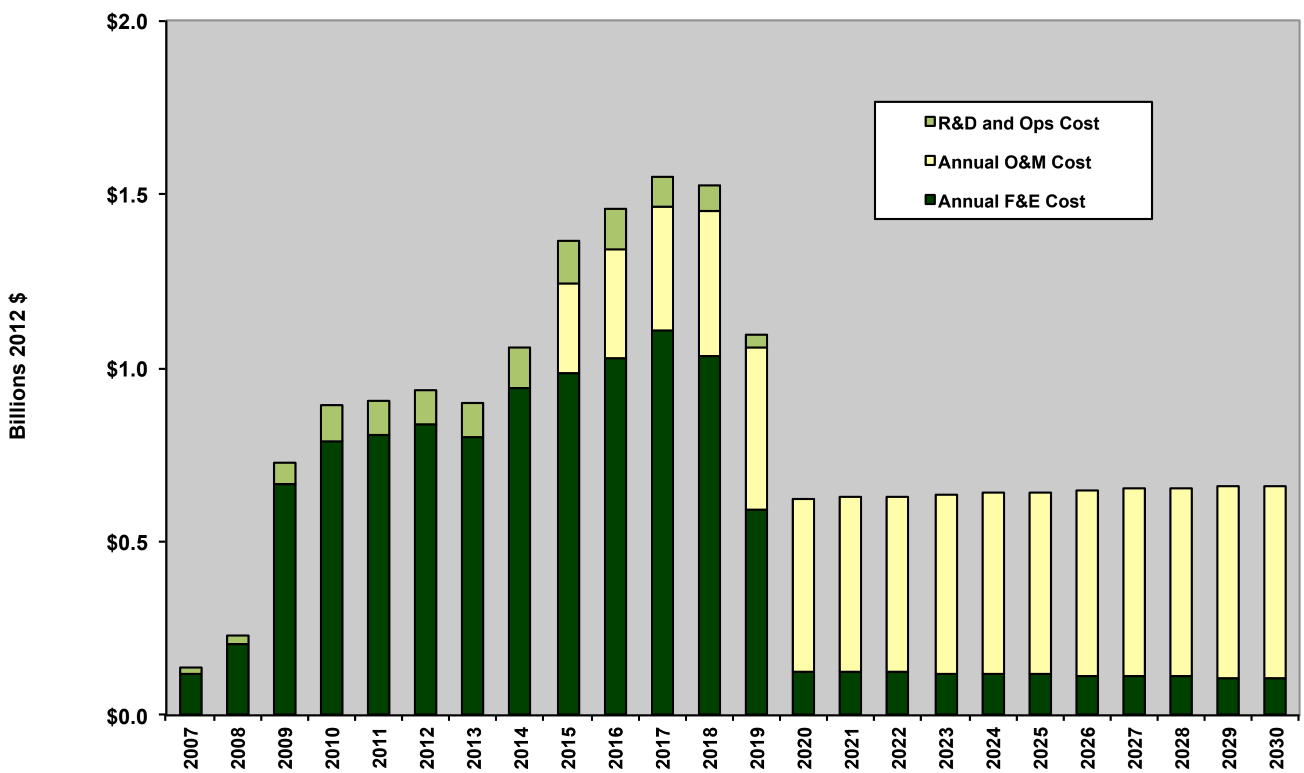


Figure 11. Annual FAA Cost for NextGen Mid-Term Capabilities

COSTS TO AIRCRAFT OPERATORS

A large number of mid-term operational improvements require not only FAA infrastructure and procedures, but also avionics onboard the aircraft. In the case of Performance Based Navigation and data communications via the Future Air Navigation System (FANS) 1/A+, versions of the necessary avionics are available and are already on board many aircraft. In the case of Automatic Dependent Surveillance–Broadcast (ADS-B) Out, specific solutions are currently being made available, while others are awaiting certification. For ADS-B In, some avionics are now available, but standards are still evolving, and further development is ongoing.

The benefits contained in this report assume a certain equipage level throughout the commercial and general aviation fleets. That does not necessarily mean that aircraft operators must equip at these levels, but it does constitute what may be considered a "target" level of equipage. In order to be consistent with our benefit estimates, the costs we estimate for avionics are based on this target level.

Operators can install new avionics on existing aircraft (retrofit) or purchase a new aircraft with the avionics already installed (forward fit). Generally, a retrofit is assumed to be more expensive than a forward fit because it involves taking the aircraft out of service to install new equipment. Forward fits are assumed to include only the cost of hardware and software, while retrofits also include the additional cost of installation[11].

Avionics packages have different costs, with FANS 1/A+ (Data Communications) and ADS-B Out generally being the least expensive and Required Navigation Performance (RNP) and ADS-B In being the most expensive. The cost to retrofit avionics, for example RNP, can also vary greatly depending on aircraft type and date of manufacture. For this analysis, we used an estimated average cost by major aircraft type, split between forward fit and retrofit. Our unit cost estimates, shown in Table 4, were derived from work done by the MITRE Corporation in support of the RTCA NextGen Mid-Term Implementation Task Force [14].

Table 4. Estimated Unit Cost (Installed) for Major NextGen Avionics Packages

	Unit Cost by Aircraft Type (thousands Fiscal Year 2012 dollars)							
	Data Communications (FANS 1/A+)		ADS-B Out		ADS-B In (CDTI)		RNP 0.3 with RF Legs	
	Retrofit	Forward Fit	Retrofit	Forward Fit	Retrofit	Forward Fit	Retrofit	Forward Fit
Commercial								
Wide- body	$80	$40	$135	$70	$500	$300	$525	$260
Narrow- body	$80	$40	$150	$70	$500	$300	$525	$260
Regional Jet	$80	$40	$130	$70	$500	$300	$525	$260
Turboprop	$80	$40	$150	$70	$500	$300	$525	$260
General Aviation								
Turboprop	$80	$40	$15	$10	$30	$30	$260	$130
Jet	$80	$40	$15	$10	$30	$30	$260	$130
Piston	N/A	N/A	$14	$8	$30	$30	N/A	N/A

* Formerly NextGen Network Enabled Weather

MITRE provided estimates of current levels of avionics equipage. Combining current equipage levels with the target future equipage levels and applying the unit cost estimates results in the total cost of avionics investment required, shown in Fig. 12.

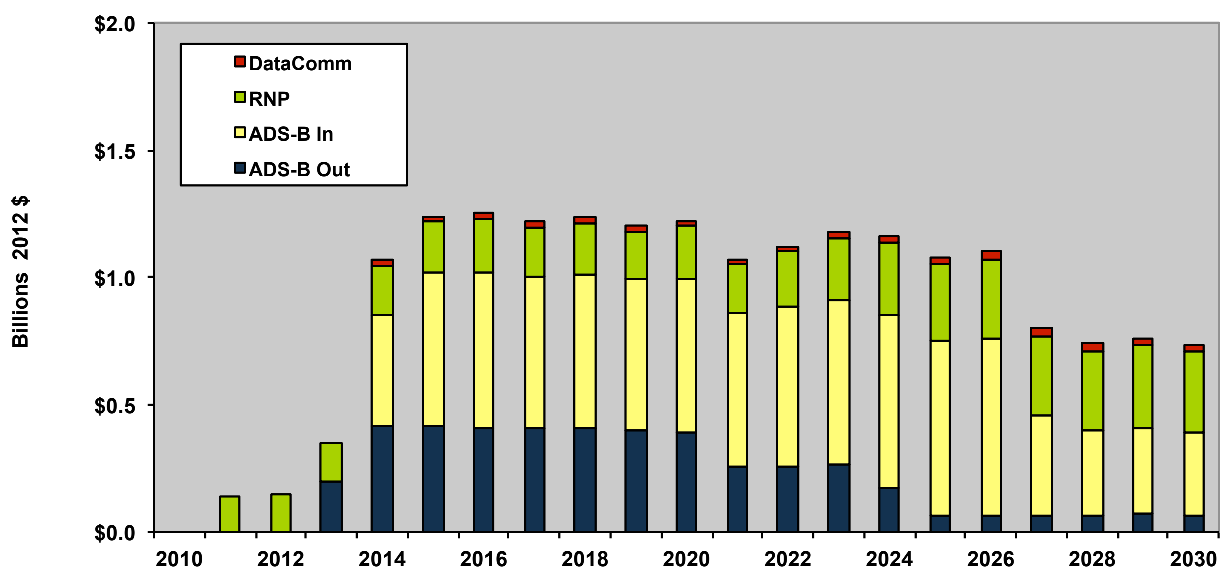


Figure 12. Estimated Annual Operator Investment in NextGen Avionics by Type

[11] Our estimated retrofit costs include direct installation. They do not include the opportunity cost of taking an aircraft out of service or ancillary costs such as training, etc.

Before concluding this section, it is worth emphasizing two points. First, estimating the total cost to equip the fleet is difficult. Not only are the costs to equip highly variable by type of aircraft, and type of airframe, these costs can also vary depending on whether avionics are installed separately or in combination with other avionics (minimizing combined installation costs). Trying to be conservative in our net benefit estimates, we assumed that each avionics package would be installed separately. In reality, operator decisions to jointly retrofit with multiple technologies would presumably reduce their costs.

The second point is that we have also been conservative in assuming a significant cost for forward fit equipage. Industry experts repeatedly state that if the avionics are included on the new aircraft, there would be "no charge" for it. While this may be true in terms of the "bill of sale," it simply does not stand to reason that the electronics are free simply because they are not an optional item. Fig. 13 shows our estimated annual avionics costs, broken out between retrofit and forward fit.

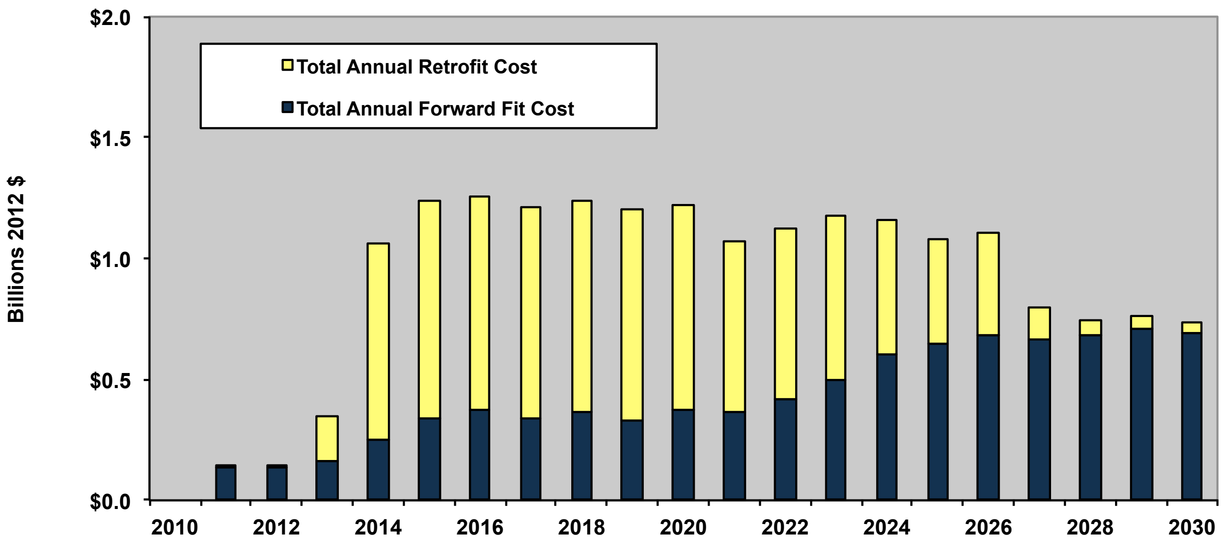


Figure 13. Estimated Annual Operator Investment in NextGen Avionics, Retrofit vs. Forward Fit

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ACRONYMS AND ABBREVIATIONS

4-D	Four Dimensional
ACM	Adjacent Center Metering
ADOC	Aircraft Direct Operating Cost
ADS-B	Automatic Dependent Surveillance–Broadcast
ADS-C	Automatic Dependent Surveillance–Contract
ARTCC	Air Route Traffic Control Center
ASIAS	Aviation Safety Information Analysis and Sharing
ATC	Air Traffic Control
BADA	Base of Aircraft Data
CATM	Collaborative Air Traffic Management
CATMT	Collaborative Air Traffic Management Technologies
CIP	Capital Investment Plan
DoD	Department of Defense
FAA	Federal Aviation Administration
F&E	Facilities and Equipment
FANS	Future Air Navigation System
GBAS	Ground Based Augmentation System
GPS	Global Positioning System
IFR	Instrument Flight Rules
ITP	In-Trail Procedure
JPDO	Joint Planning and Development Office
METAR	Meteorological Aerodrome Report
NAS	National Airspace System
NCWD	National Convective Weather Diagnostic
NextGen	Next Generation Air Transportation System
NPV	Net Present Value
NVS	NAS Voice System
O&M	Operations and Maintenance
OI	Operational Improvement
PBN	Performance Based Navigation
PVT	Passenger Value of Time
R&D	Research and Development
RNAV	Area Navigation
RNP	Required Navigation Performance
RTCA	Aviation Industry Group
SCC	Social Cost of Carbon
SUA	Special Use Airspace
SWAC	System Wide Analysis Capability
SWIM	System Wide Information Management
TBFM	Time Based Flow Management
TBM	Time Based Metering
TMA	Traffic Management Advisor
VFR	Visual Flight Rules

Why NextGEN Matters

The movement to the next generation of aviation is being enabled by a shift to smarter, satellite-based and digital technologies and new procedures that combine to make air travel more convenient, predictable and environmentally friendly.

As demand for our nation's increasingly congested airspace continues to grow, NextGen improvements are enabling the FAA to guide and track aircraft more precisely on more direct routes. NextGen efficiency enhances safety, reduces delays, saves fuel and reduces aircraft exhaust emissions. NextGen is also vital to preserving aviation's significant contributions to our national economy.

- NextGen provides a better travel experience, with less time spent sitting on the ground and holding in the air.
- NextGen gets the right information to the right person at the right time.
- NextGen reduces aviation's adverse environmental impact.
- NextGen lays a foundation for continually improving and accommodating future air transportation needs while strengthening the economy locally and nationally.
- NextGen increases airport access, predictability and reliability.
- NextGen enables us to meet our increasing national security and safety needs.
- NextGen safety management helps us to proactively identify and resolve potential hazards.
- NextGen brings about one seamless, global sky.

U.S. Department of Transportation
Federal Aviation Administration

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